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ORIGINAL ARTICLE

Alterations in Interleukin-8, High Sensitivity C-reactive Protein and Some Hematological Parameters Uncover Ongoing Pathologic Process in Bakery Workers Exposed to Flour Dust

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Abstract

Background: Exposure to flour dust has been linked to the emergence of respiratory symptoms. This study assessed the levels of some inflammatory markers and hematological parameters among bakery workers exposed to flour dust in Ota, Nigeria.
Methods: A total of 100 participants (50 bakery workers with exposure to flour dust and 50 non-bakery workers without such exposure) took part in this study. The participants' peak expiratory flow rate was measured using a peak flow meter. Blood samples were assessed for high sensitivity-CRP, interleukin-8, and a complete blood count. The collected data was analyzed using SPSS version 23.0.
Results: The outcomes revealed that bakery workers demonstrated significantly ($p \leq 0.05$) elevated levels of high sensitivity-CRP, interleukin-8 concentrations, red blood cells, hemoglobin concentration, packed cell volume, platelets, and lymphocytes compared to non-bakery workers ($p \leq 0.05$). Meanwhile; the mean absolute neutrophil count and neutrophil-lymphocyte ratio of the bakery workers were found to be significantly ($p \leq 0.05$) lower compared to non-bakery workers.
Conclusion: This study underscores the health risks faced by bakery workers exposed to flour dust, as evidenced by alterations in inflammatory markers and hematological parameters. These findings highlight the ongoing pathological processes induced by flour dust exposure, emphasizing the need for preventive measures and occupational health interventions in bakery settings. Enhanced awareness and protective measures are imperative to mitigate the adverse health effects associated with flour dust exposure in occupational environments. Further research is warranted to elucidate the mechanistic pathways underlying these observed alterations and to develop targeted interventions for mitigating occupational health risks in bakery workers.

Keywords: Occupational Exposure, Inflammatory Markers, Respiratory Health, Occupational Hazards, Flour Dust Exposure

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INTRODUCTION

Work-related contact with flour dust has been linked to various allergic ailments, such as periodic or sustained asthma, conjunctivitis, rhinitis, and contact dermatitis [1]. These conditions have been associated with extended inhalation exposure to cereal flours, like wheat and rye, along with the enzymes found within them. These factors have been connected to multiple allergic disorders, including occupational asthma [2]. Several of these health issues, notably asthma, which remains prevalent among bakery workers, have been increasing due to the rising global and local demand for baked goods [3]. Bakery operations, which involve tasks like flour sifting, dough preparation, mixing flours, shaping, and cutting, expose workers to wheat dust and potentially allergenic elements like fungal α-amylase [4].

Baker's asthma doesn't solely affect bakers; it also impacts confectioners, pastry factory employees, flour mill workers, and food processors that come into contact with these allergens [5]. According to recent data from the Surveillance of Work-Related and Occupational Respiratory Disease, Baker's asthma is the second most frequent cause of occupational asthma in the UK [6]. Similar studies conducted in Nigeria have indicated an increase in work-related asthma cases, including among bakers serving a rapidly growing baked goods industry that has become a staple in the country, from street food to homemade meals [7].

Common symptoms of Baker's asthma include rhinitis, heightened bronchial responsiveness, and reversible airflow obstruction [8]. The most prevalent IgE antibodies detected

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in Baker's asthma or rhinitis are those targeting grain flours like wheat, rye, and barley [9]. Contact sensitivity, atopic dermatitis, eczema, and urticaria all seem to be interconnected, with the hydrophobic prolamin components of wheat being the likely causative factor [10]. Repeated exposure can lead to increasingly severe reactions, including conjunctivitis and skin symptoms [11].

Bakers frequently exhibit atopic traits based on skin or IgE tests. Symptoms may emerge months, years, or even decades after a period of latency, and they initially correlate with periods of bakery work. Upon leaving the bakery environment, respiratory problems can persist. The diagnosis of baker's asthma has traditionally relied on sensitization to flour, but achieving accurate management of these health consequences necessitates early identification via a specific biomarker, a challenge given the delayed onset of symptoms. This study seeks to examine the levels of some inflammatory markers and hematological parameters among occupationally exposed bakers in Ota, Ogun State, Nigeria, aiming to investigate potential ongoing pathological effects resulting from exposure to flour dust.

METHODS

Study Design

The research employs a case-control design.

Study Location

This investigation was conducted among bakery employees at selected bakeries situated in Ota, Ogun State. Ota is a town in the southwestern region of Nigeria, located at coordinates (Latitude 6°41′00″ N, Longitude 3°41′00 ° E). Ogun State shares borders with Lagos State to the south, Oyo and Osun States to the north, Ondo State to the east, and the Republic of Benin to the west.

Study Population

A total of 100 individuals took part in this study. Among them, 50 were bakery workers with a minimum of 5 years of work experience, and the other 50 were individuals not employed at or residing near bakeries, serving as the control group. Each participant provided informed consent, underwent blood sample collection, and completed questionnaires to gather essential demographic and medical information.

Laboratory Analysis

The levels of hs-CRP and Interleukin-8 (Il-8) were assessed using the ELISA technique according to the methods described by Ebrahimi et al. [12] and Endo et al. [13], respectively. Additionally, various blood parameters including packed cell volume (PCV), total white blood cell count and differential (Neutrophil, Lymphocyte & Mean intermediate), red cell count, hemoglobin concentration, and red cell indices (mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration) along with platelet count were analyzed using the Mindray BC-2800 hematology auto analyzer as described by Samuel et al [14].

Statistical Analysis

Statistical analysis was conducted utilizing Statistical Package for Social Sciences (SPSS) software version 23.0. To compare mean differences between the groups, Student's t-test was employed. Pearson's correlation was used to establish relationships among the parameters studied.

RESULTS

A total of 100 participants took part in the research study. This group consisted of 50 individuals employed in bakeries and another 50 individuals who were not bakery workers, serving as the control group.

The data presented in Table 1 displays the mean±standard deviation of the study participants. A notable and statistically significant rise was observed in the mean levels of hs-CRP and IL-8 concentration when compared to the control group. In terms of the mean peak expiratory flow rate, the control group (non-bakery workers) exhibited a slightly higher value than the bakery workers, though this difference did not reach statistical significance ($p \geq 0.05$).

Moving on to Table 2, a statistically significant increase was noted in the lymphocyte count within the test group when compared to the control group. Conversely, there was a statistically significant decrease in both the neutrophil count and MID (mean intermediate) of the test group compared to the control group. Additionally, the test group displayed a statistically significant increase in PCV (packed cell volume), HGB (hemoglobin), and RBC (red blood cell) counts in comparison to the control group.

The relationships between Peak Expiratory Flow Rate, hs-CRP, and IL-8 concentration were explored in Table 3 for non-bakery workers (control subjects). The results indicated a lack of significant positive correlation between Peak Expiratory Flow Rate and hs-CRP concentration ($r=0.44$, $p=0.762$). Similarly, a non-significant negative correlation was observed between Peak Expiratory Flow Rate and IL-8 ($r=-0.71$, $p=0.626$), as well as between hs-CRP and IL-8 concentration ($r=-0.121$, $p=0.404$).

In Table 4, the correlations between Peak Expiratory Flow Rate, hs-CRP, and IL-8 concentration were investigated within the bakery worker group (test subjects). Notably, a significant negative correlation was identified between Peak

Table 1. Comparison of inflammatory markers and respiratory peak flow between case and control

Variables	Case $\bar{X}$±SD	Control $\bar{X}$±SD	P-Value
Peak flow (L/min)	346.6 ± 86.32	359.0 ± 102.92	0.520
HsCRP (mg/dl)	0.0338 ± 0.0031	0.0158 ± 0.0021	0.002*
IL-8 (pg/ml)	483.2 ± 21.9	189.1± 24.6	<0.001*

**statistically significant at P < 0.005*

Table 2. Comparison of hematological parameters between case and control

Variables	Case $\bar{x} \pm SD$	Control $\bar{x} \pm SD$	P-value
WBC (10^3/μL)	7.08 ± 2.79	6.92 ± 2.06	0.748
NEUTROPHIL (%)	51.56 ± 8.69	57.83 ± 11.26	0.001*
LYMPHOCYTE (%)	40.66 ± 8.36	33.51 ± 9.97	<0.001*
MID (%)	7.78 ± 1.74	8.66 ± 2.21	0.0036*
HGB (g/dL)	13.64 ± 1.90	12.38 ± 1.83	0.002*
RBC (10^12/L)	5.38 ± 0.75	4.94 ± 0.64	0.003*
PCV (%)	40.82 ± 5.33	36.81 ± 4.99	0.001*
MCV (fL)	76.13 ± 4.71	74.80 ± 5.09	0.189
MCH (pg)	25.36 ± 1.91	25.05 ± 1.81	0.427
MCHC (g/dL)	33.33 ± 1.05	33.54 ± 0.82	0.287
PLT (10^9/L)	354.90 ± 141.56	289.20 ± 104.35	0.018*
NLR	1.37 ± 0.62	2.13 ± 1.59	0.001*

**statistically significant at P < 0.005*

Table 3. Pearson's correlation of peak flow rate, hs-CRP AND IL-8 concentration in control group

Variables		PFC	hsCRPC	IL8C
PFC	Pearson Correlation		.044	-.071
	Sig. (2-tailed)	--	.762	.626
hsCRPC	Pearson Correlation	.044	--	-.121
	Sig. (2-tailed)	.762		.404
IL8C	Pearson Correlation	-.071	-.121	--
	Sig. (2-tailed)	.626	.404	

Table 4. Pearson's correlation of peak flow rate, hs-CRP AND IL-8 concentration in Test group

		PFT	**HsCRPT**	**IL8T**
PFT	Pearson Correlation		.045	-.308*
	Sig. (2-tailed)	--	.756	.030
HsCRPT	Pearson Correlation	.045		-.027
	Sig. (2-tailed)	.756	--	.851
IL8T	Pearson Correlation	-.308*	-.027	
	Sig. (2-tailed)	.030	.851	--

**statistically significant at P < 0.005*

Expiratory Flow Rate and IL-8 concentration (r=-0.308, p=0.030). However, the correlation between Peak Expiratory Flow Rate and hs-CRP concentration was not statistically significant (r=0.045, p=0.756). Likewise, no significant correlation was found between hs-CRP and IL-8 concentration (r=-0.027, p=0.851).

DISCUSSION

The inhalation of flour dust stands as a significant occupational risk within the baking sector, impinging on the respiratory well-being of workers. This particulate matter arises predominantly from diverse baking tasks such as flour measurement, sifting, ingredient combination, to name a few [15]. Long-term inflammatory alterations are facilitated through the release of specific agents encompassing cytokines and growth factors. These cytokines, generated by inflammatory cells, assume a crucial function in orchestrating and sustaining the prolonged inflammatory

mechanisms in the respiratory pathways during cases of chronic inflammation [16].

The study assessed the levels of high-sensitivity C-reactive protein (hs-CRP) in bakery workers in comparison to a control group. The findings indicated that hs-CRP levels were notably elevated among the bakery workers, suggesting a likelihood of inflammation in this group. This research suggests that the bakers were likely experiencing an inflammatory process, as hs-CRP is a sensitive marker for inflammation.

Hwang *et al.* [17] conducted a similar study to determine the effect of inorganic dust exposure on retired workers that can cause Chronic obstructive Pulmonary Disease (COPD) and pulmonary inflammatory. hs-CRP was one of the 6 inflammatory markers measured and it was found that hs-CRP was among the 3 markers which were significantly higher in the workers. According to Kimata and Lindley [18], Interleukin-8 (IL-8) is a crucial chemotactic agent that signals neutrophil recruitment and activation. It can be secreted by many structural and immune cells, including smooth muscle cells, bronchial epithelial cells and macrophages. Elevated levels of IL-8 have been observed in induced sputum or broncho-alveolar lavage fluid of individuals with asthma, indicating its potential involvement in inflammation-related diseases.

In a study by Al-Katib & AL-Hakkak[19], who investigated inflammatory markers in individuals exposed to wheat flour dust, notable increases in serum IL-8 levels were identified among millers compared to a control group. The statistical analysis demonstrated significant differences at a significance threshold of $P \leq 0.005$.

Similarly, Tolinggi *et al.* [20] investigated the impact of inhaling limestone dust on IL-8 levels, contrasting miner workers with district office workers as controls. The study found a statistically significant elevation ($p \leq 0.05$) of IL-8 among miner workers. These results parallel our current study, as the concentration of IL-8 in the serum of bakery workers was also found to be statistically significant ($p \leq 0.05$) when compared to non-bakery workers, revealing a consistent pattern in individuals exposed to inorganic dust.

Peak expiratory flow rate (PEFR) signifies the maximum flow rate generated during forceful exhalation, initiated from full lung inflation, and primarily reflects larger airway flow. This measure relies on a person's voluntary effort and muscular strength [21]. In our investigation, we observed a rise in the average PEFR among bakery workers compared to non-bakery workers in Ota, Ogun state. However, this disparity did not achieve statistical significance ($p \geq 0.05$). This outcome differs from the findings of Ajayeoba et al. [21], who evaluated the PEFR of bakers in Osun, Lagos, and Oyo states, reporting a statistically significant outcome ($p \leq 0.05$).

Moreover, the findings derived from this investigation demonstrated a noteworthy rise ($p \leq 0.05$) in lymphocyte levels, accompanied by a significant reduction ($p \leq 0.05$) in neutrophil and MID values among individuals employed in bakery settings in comparison to those not engaged in bakery-related work. A previous study conducted by Al-Hakkak & Al-Katib [19] reported a similar escalation in lymphocyte counts, attributing it to the body's defense mechanism that strives to generate additional antibodies to counteract the impact of inhaled substances within the bakery environment. In contrast, the outcomes of this study diverge from the report by Saleh *et al.* [22] regarding the influence of high temperatures on hematological parameters in bakery workers, as their research indicated a substantial decline in lymphocyte levels compared to control groups. This inconsistency could potentially be attributed to differences in the duration of exposure and socio-demographic characteristics among the participants. Whether significant alterations in neutrophil and MID values were observed remains undisclosed in their report [23].

In a study undertaken by Forget *et al.* [24], the investigation centered on determining the standard value for the neutrophil-to-lymphocyte ratio. The findings highlighted a reciprocal connection between neutrophil and lymphocyte levels, indicating that as neutrophil counts rose, lymphocyte counts declined, and vice versa. This outcome aligns with the conclusions of the current study. This shift in numbers could potentially be linked to ongoing inflammation within the lung or bronchial passages due to consistent inhalation of flour dust and other baking-related substances.

Similarly, in the present study, notable increases (with a significance level of $p \leq 0.05$) were observed in the hemoglobin concentration, red blood cell count, and packed cell volume among bakery workers in comparison to those who did not work in bakeries. This phenomenon might be attributed to the continual inhalation of emissions from bakery chimneys. This exposure places bakery workers at a disadvantage in terms of oxygen intake. In response, the body enhances its oxygen-carrying capacity, subsequently leading to elevated hemoglobin and red blood cell production. Another potential factor is dehydration resulting from strenuous labor and working in conditions of heat stress. Such conditions could reduce blood plasma volume and amplify red blood cell counts. These results are consistent with earlier investigations conducted by Al-Katib and Al-Hakkak [19]. Moreover, they align with a recent study conducted by Christian and co-authors [25], which delved into the impact of smoke inhalation on "Bole" roasters, revealing a substantial increase in packed cell volume (PCV) levels among the roasters (test subjects), attributed to smoke exposure. However, noteworthy variations in red blood cell count and hemoglobin levels were not documented in that study.

Furthermore, this study reveals an inverse correlation between the peak expiratory flow rate and IL-8 (correlation coefficient $r=-0.308$, $p=0.030$). This implies that as one variable increases, the other decreases. This finding can be attributed to prolonged exposure to flour, which can lead to lung metabolism and toxic mechanisms. Consequently, a reduced peak expiratory flow rate and elevated serum concentration of inflammatory biomarkers might occur. Interestingly, this outcome is consistent with the results of Watanabe et al. [26], who similarly noted a significant association between increased IL-8 levels and decreased peak expiratory flow rate.

Contribution to knowledge

This study offers several significant contributions to our comprehension of the health consequences linked to on-the-

job exposure to flour dust in bakery personnel: 1) The investigation recognizes specific markers of inflammation, namely high sensitivity-CRP and interleukin-8, that exhibit increased levels in bakery workers who come into contact with flour dust. This provides valuable insights into the physiological reactions and potential health implications stemming from such exposure. 2) Through the evaluation of peak expiratory flow rate (PEFR), the study sheds light on the plausible respiratory effects of exposure to flour dust. While the observed differences in PEFR did not reach statistical significance, the study contributes to the ongoing discourse concerning respiratory well-being among bakery workers. 3) The study uncovers notable alterations in hematological indicators, encompassing red blood cell count, hemoglobin concentration, and packed cell volume, within bakery employees. These discoveries expand our comprehension of the systemic consequences of being exposed to flour dust. 4) The research accentuates the likelihood of bakery workers developing allergic ailments due to recurrent exposure to flour dust. This underscores the urgency for safeguarding measures and health monitoring to forestall the emergence of persistent conditions. 5) Conducted in Nigeria, the study extends insights into the health hazards encountered by bakery personnel in a particular geographical milieu. This contextual insight proves invaluable for tailoring interventions and policies aimed at addressing local work-related health challenges. 6) The study advocates for the adoption of personal protective gear and proper workplace protocols among bakery workers. This contributes to ongoing endeavors to raise awareness about the health perils linked to job-related exposures and to foster preemptive measures. 7) By exploring the correlations between biomarkers, respiratory metrics, and hematological indicators, the study enriches the comprehension of the intricate interplay between exposure, inflammation, and health consequences.

Public Health Implications

This study offers valuable insights into potential health hazards linked with the occupational exposure of bakery workers to flour dust. Primarily, the study underscores that bakery employees consistently exposed to flour dust face a risk of chronic inflammation and possible respiratory ailments. This underscores the necessity for heightened measures to safeguard their health, such as improved ventilation systems, regular health evaluations, and the use of proper personal protective gear, like masks, to minimize dust inhalation. Secondly, the findings of the investigation can aid in formulating occupational health and safety regulations tailored to the protection of bakery staff. These regulations might encompass guidelines concerning permissible levels of flour dust exposure, compulsory utilization of protective gear, and routine health assessments to identify early signs of respiratory problems. Thirdly, the study emphasizes the significance of health education initiatives targeting both bakery workers and employers. Workers need to be educated about the potential health risks tied to flour dust exposure, appropriate hygiene protocols, and the correct usage of protective equipment. Employers can contribute to cultivating a safe working environment and encouraging preventive measures. Fourthly, the pinpointing of specific biomarkers, such as high sensitivity-CRP and interleukin-8, has the potential to facilitate early recognition of inflammatory processes in bakery workers. This early detection could enable timely interventions and treatments, thereby averting the progression of respiratory ailments. Fifthly, the study's outcomes can serve as substantiation to advocate for policy alterations within the industry and governmental spheres. This advocacy might encompass promoting the adoption of safer technologies, encouraging research into alternative flours with lower allergenicity, and championing improved standards for worker protection. Lastly, the research contributes to the expanding reservoir of knowledge concerning the health hazards tied to the occupational exposure of bakery workers to flour dust. This could stimulate further research into strategies for prevention, alternative work methodologies, and medical interventions to mitigate the health consequences for bakery workers.

Limitations of the study

While this study imparts valuable insights into the potential health hazards linked with occupational contact with flour dust among bakery workers, it's essential to acknowledge its limitations, these include: 1) The research employs a cross-sectional design, which captures information at a solitary juncture. This approach renders the establishment of cause-and-effect relationships or determination of associations' direction arduous. Longitudinal studies that track individuals over time would furnish more resilient substantiation regarding the enduring health repercussions of flour dust exposure. 2) The research fails to consider potential confounding variables that could sway the outcomes. Factors like age, smoking history, underlying health conditions, and other on-the-job exposures (e.g., to other allergens or irritants) could impact the results, yet they aren't comprehensively addressed in the analysis. 3) The investigation hinges on self-reported data from participants, involving occupational background and medical details. Self-reporting could be prone to recollection bias and might not consistently mirror participants' genuine exposures or health statuses. 4) The study is carried out in a specific geographical area (Ota, Ogun State, Nigeria), which could constrain the applicability of findings to other regions with distinct environmental conditions, workplace customs, and population demographics. 5) Though the research detects heightened levels of high sensitivity-CRP and interleukin-8 among bakery workers, these biological markers aren't exclusive to flour dust exposure. Other factors such as infections or non-occupational exposures might also sway these biomarker levels. 9) The research incompletely addresses the potentiality of reverse causation, wherein pre-existing health conditions could impact participants' occupation selection or work performance. 10) The study doesn't explore possible ethnic or genetic factors that could influence individual susceptibility to flour dust exposure and associated health consequences. However, notwithstanding these limitations, the study augments our comprehension of the health hazards associated with flour dust exposure and

establishes a framework for subsequent investigations and public health campaigns in this domain.

Recommendations for future studies

To expand on the findings of this study and enhance our comprehension of the health hazards linked to the inhalation of flour dust among bakery employees, future research could take into account the following suggestions: 1) Conduct extended longitudinal studies that monitor bakery personnel over a prolonged period to observe transformations in health outcomes, levels of biological markers, and respiratory function. Longitudinal approaches can shed light on the accumulated consequences of flour dust exposure and aid in establishing cause-and-effect relationships. 2) Increase the size of the sample and ensure inclusivity in terms of demographic attributes, work roles within the bakery, and geographical locations. This step would enhance the applicability of findings across different populations and circumstances. 3) Consider potential variables that could confound results, such as age, history of smoking, pre-existing health conditions, and other job-related exposures. Gather thorough data about participants' health status and lifestyle factors to better segregate the impacts of flour dust exposure. 4) Compare the health repercussions of distinct flour types and bakery settings. Different flours might encompass diverse allergenic constituents that could impact health outcomes in dissimilar ways. 5) Explore a broader array of indicators that specifically pertain to respiratory health and inflammation, encompassing lung function tests like spirometry, inflammatory cytokines, and markers of oxidative stress. This could yield a more comprehensive grasp of the underlying biological mechanisms. 6) Investigate plausible genetic elements that could predispose individuals to health effects related to flour dust exposure. Genetic variances could contribute to varying responses to such exposure. 7) Institute on-site environmental monitoring to gauge the levels of flour dust and potential allergenic elements in diverse bakery environments. This will offer more precise assessments of exposure and facilitate the correlation of exposure levels with health outcomes. 8) Conduct intervention studies to assess the efficacy of measures such as enhanced ventilation systems, respiratory safeguards, and modifications in work practices in diminishing flour dust exposure and its consequent health impacts. 9) Compare the health effects of flour dust exposure among different occupational clusters with exposure to other particulate matter, like construction laborers or miners. This might furnish insights into the distinctive risks posed by flour dust. 10) Investigate plausible variations in health effects and allergenic constituents of flour dust across distinct geographical regions, considering factors like climate, soil composition, and varieties of cultivated grains and 11) Collaborate with specialists from varied disciplines such as occupational health, epidemiology, toxicology, and respiratory medicine to achieve a comprehensive understanding of the health hazards and potential alleviation strategies. By addressing these recommendations, impending studies can contribute to a more all-encompassing and nuanced comprehension of the health implications of flour dust exposure among bakery personnel. This, in turn, can guide effective interventions and policies to safeguard their well-being.

CONCLUSION

This research uncovers a noteworthy contrast in the serum levels of high sensitivity-CRP, interleukin-8, and certain hematological measures between employees in the bakery industry and those not engaged in bakery-related work. Although the average PEFR value among bakery workers was slightly greater compared to non-bakery workers, this disparity lacks statistical significance. Furthermore, a substantial inverse correlation was observed between PEFR and IL-8 concentration. Based on the findings of this study, it might be inferred that individuals occupationally exposed to flour dust in baking professions might encounter compromised health due to this exposure, leading to a heightened susceptibility to allergic diseases over time. Consequently, advocating for the diligent use of personal protective equipment is strongly recommended for individuals pursuing a career in baking.

Declarations

Ethical approval and consent to participate

This study was approved by the Babcock University Health Research Ethics Committee (BUHREC) with the ethical registration number: BUHREC205/228/22. Participation was entirely voluntary, and all study participants provided their written consent by means of consent forms dully signed before their involvement.

Consent for publication

All participants gave consent for publication

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of interest: None to be declared.

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Authors' contributions

OEO, EOI, TOO and SSE conceptualized the study. OEO, EOI, TOO, CON, FAL, ENA, SSE, OFO and YY acquired and analyzed the data. ENA, SSE and OFO performed the statistical analysis. OEO, EOI, TOO, CON, FAL, ENA and SSE interpreted the data and prepared the draft. OEO, EOI, TOO and SSE supervised the project. All authors read and approved the final manuscript.

List of Abbreviations

BUHREC: Babcock University Health Research Ethics Committee
COPD: Chronic Obstructive Pulmonary Disease WBC: White Blood Cell
ELISA: Enzyme-Linked Immunosorbent Assay
hs-CRP: high sensitivity-CRP
IL-8: Interleukin-8
MCH: Mean Corpuscular Hemoglobin
MCHC: Mean Corpuscular Hemoglobin Concentration

MCV: Mean Corpuscular Volume
NLR: Neutrophil-Lymphocyte Ratio
PCV: Packed Cell Volume
PEFR: Peak Expiratory Flow Rate
PLT: Platelet
RBC: Red Blood Cell
SPSS: Statistical Package for Social Sciences
UK: United Kingdom
USA: United States of America

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